

THE
HEADS
OF A
COURSE of LECTURES
IN
Experimental Philosophy.

CAMBRIDGE,

Printed by J. BENTHAM, Printer to the University;

MDCCXLVI.



MECHANICS.

1. **T**HE uses of experiments in natural Philosophy.

2. Several kinds of force, by which bodies act upon each other.

3. Glass planes attract each other at a sensible distance.

4. They attract water, and raise it between them.

5. A line drawn along the surface of the water, when the planes are nearer at one end than at the other, is an hyperbola.

6. Other fluids will ascend along these planes inclined to each other, and to the horizon.

7. The attraction varies according to different laws, when the planes are dry, and when wetted with the fluid, which rises between them.

8. Metals cohere so strongly by attraction, as to sustain great weights.

9. The force, by which the magnet draws iron, passes through the densest bodies.

10. Iron, differently applied to it, either stops the force, or makes it extend to greater distances.

11. A needle touched upon one pole of the magnet, is afterwards repelled by it, and attracted by the other.

12. Iron or steel gains the virtue of a magnet, by being rubbed upon it;

13. And loses it again, by being rubbed in the contrary direction :

14. The same virtue is given it by cooling it, when heated, in a vertical position; by letting it stand long in that position; by hammering, filing, &c.

15. The force of the magnet's attraction at different distances.

16. Mercury is attracted by gold or silver, and repelled by iron.

17. Electrical bodies attract and repel others.

18. Their forces pass through the densest bodies,

19. And may be communicated to all bodies not of themselves electric.

20. This attraction is perceived at great distances;

21. It is attended with sparks of fire coming from all parts of the body, to which the electricity is communicated.

22. The causes hitherto assigned for these actions of the parts of matter upon each other, are hypothetical and insufficient.

23. There are a kind of glass bubbles, any part of which being broken off, the whole bursts into very small pieces.

24. Some account may be given of this phenomenon from the principles hitherto explained.

25. Even

25. Even the densest bodies abound with pores.

26. The constituent parts of all bodies are exceedingly minute.

27. From hence it happens that fluids will infiltrate themselves into all bodies, and that sometimes a mixture of two fluids shall be less in bulk, than when they are separate.

28. Motion is either absolute or relative.

29. The velocity of an uniform motion is measured by the space it describes in a given time.

30. The quantity of motion in any body is measured by its velocity and quantity of matter jointly.

31. Equal forces produce equal quantities of motion in bodies of different magnitudes.

32. The laws of motion cannot be proved by single experiments, but are general rules founded upon continual observations. The rules are these :

33. The direction and quantity of the motion in any body are never altered but by some external cause ;

34. Nor is the direction or quantity of any motion altered, when the whole or any part of it passes out of one body into another.

35. No motion is ever produced in any direction, without another equal to it in the opposite direction.

36. When a body is at once impelled by two forces, whose directions and quantities are given,

the direction and velocity of the body may be known.

37. From hence the directions and quantities of three forces may be determined, which acting upon the same body, will keep it at rest.

38. Two forces acting upon the arms of a balance or lever are in æquilibrium when they are reciprocally, as the perpendicular distances of the lines of their directions from the center.

39. It is of no consequence upon what point in the line of its direction the force acts.

40. If there is a greater number of forces, the æquilibrium is, when their quantities being multiplied into their respective distances, the sums of the products on each side the center are equal.

41. These rules are applicable to bent and compound levers, as also to scales, steelyards, and other instruments of that kind.

42. The methods by which a balance becomes useless or deceitful.

43. In the wheel and axle the æquilibrium is, when the force applied to the wheel, is to that applied to the axle, as the radius of the axle, to that of the wheel.

44. The fusee of a watch may be so adjusted to the decreasing force of the spring while it expands itself, that it shall act always with the same strength upon the wheels.

45. If

45. If a body is suspended with a single pully, the force equals half the weight.

46. If there are 2, 3, 4 or more pullies, each of which has a separate string, the force is to the weight as 1 to 4, 8, 16, &c.

47. The difference between the weight and force is sustained by the fixed strings.

48. If the pullies all communicate with one another, the force must be to the weight, as 1, to the number of the strings at the lower pullies.

49. When a body is sustained upon an inclined plane, the force is to the weight, as the sine of the inclination of the plane, to the sine of the angle, which the direction of the force makes with a perpendicular to the plane.

50. To sustain a given body upon a given plane with the least force possible, the direction of the force must be parallel to the plane.

51. The force will then be to the weight, as the height of the plane to its length.

52. When two bodies rest upon inclined planes of the same height, and sustain each other, their weights are to each other, as the lengths of the planes, upon which they rest.

53. When two forces perpendicular to the sides of a wedge are sustained by one perpendicular to the back, the latter is to the sum of the two former, as the back of the wedge, to the sum of the sides.

54. When the direction of the forces acting upon the sides is parallel to the back of the wedge, the proportion of each of these to the third force is not the same, as that of the height of the wedge, to the back.

55. The experiments, made to prove this proportion to be just, are not applicable to this case.

56. The difficulties concerning one case of the lever, which is generally mentioned as a paradox, arise from a mistake of the same nature.

57. In the screw the æquilibrium is, when the force is to the weight, as the height of one spire, to the circumference, which the power describes.

58. In machines compounded of two or more simple ones, the forces, which sustain each other, when applied to the different parts, may be determined by the foregoing rules ;

59. Or by this general principle, that the æquilibrium is always, when the forces are to each other reciprocally, as their velocities, estimated in the lines of their directions,

60. No machine can be so contrived, that by the action of the parts upon each other, its motion shall be made perpetual.

61. No force acting upon the parts of a machine, and upon them only, can give the whole a motion in one direction.

62. This observation is not contradicted by the instance of carriages, which are so contrived, as to be moved forward by the persons, who sit in them.

63. Ma-

63. Machines never lessen the whole force necessary to perform any work, but are generally used either to diminish the force applied at once by lengthening the time, or to shorten the time by increasing the force applied at once.

64. In the rules here given no regard is had to the weight of the machine, or the friction of its parts, when they move over each other.

65. The resistance arising from friction cannot easily be determined by general rules, because it depends upon a variety of circumstances, such as the materials of the machine, the shape of its parts, the force acting upon it, &c.

66. One kind of friction depends chiefly upon the force, with which the surfaces are pressed together, and not upon their breadth.

67. To lessen the resistance arising from friction, wheel carriages are used.

68. The larger the wheels are the more is this resistance diminished.

69. The direction in which such carriages may be drawn with the least force, is parallel to the plane they move along.

70. There are several mechanical ways of finding the center of gravity of one or more bodies.

71. From them will appear the reason of several experiments, in which bodies seem to move, or to be sustained, contrary to the laws of gravity.

72. By considering the situation of the center

of gravity, it may be determined in what cases a body will slide, roll, fall, or continue at rest.

73. To sustain the center of gravity of one or more bodies, a force must be applied equal to the weight of the whole.

74. A body falling or rising either perpendicularly, or along an inclined plane, is accelerated or retarded uniformly by the force of gravity.

75. This force is proportional to the quantity of matter.

76. When a body is thus accelerated or retarded, the velocity acquired or lost will be as the time of its motion, and the space described as the square of that time or velocity.

77. The space described will be half that which would be described in the same time by the last or first velocity continued uniformly.

78. The spaces described in equal successive parts of this time taken from the beginning or end of the motion, are as the odd numbers 1, 3, 5. &c.

79. The heights of buildings, depths of wells &c. may be measured by observing the time in which a body falls through them.

80. The velocity, which a body acquires by falling from any height, will carry it again to the same height.

81. It always gains the same velocity by falling from the same perpendicular height, whether

it

it falls freely, or along inclined planes, or curves of any kind.

82. Let any number of chords be drawn in a circle, from the end of that diameter which is perpendicular to the horizon, and the time of descent through them all shall be equal.

83. The manner, in which a cycloid is generated.

84. A difficulty mentioned by *Aristotle* concerning the motion of a great and small wheel upon the same axis.

85. The manner of measuring roads by a wheel.

86. A cycloid is the line, in which a body will soonest fall from one point to another not directly below it.

87. An heavy body may be made to move in a cycloid, by hanging it between two cycloidal cheeks.

88. The space, through which a body will fall in the time of one oscillation in a cycloid, is to half the length of the string, in the duplicate ratio of the periphery of a circle, to the diameter.

89. All the oscillations of a body in the same cycloid are performed in the same time.

90. This time is equal to that, in which a pendulum of the same length oscillates in very small arcs of a circle, but widely different from that, in which a body would oscillate in any chords of the same circle.

91. The times, in which pendulums, whose
lengths

lengths are different, perform their oscillations, are in a subduplicate ratio of those lengths.

92. The manner, in which clocks are regulated by pendulums.

93. Hence we may know, how much the lengths of their pendulums must be altered in order to correct them, when they go wrong.

94. The errors observed in clocks, carried into different latitudes, arise from variations, both in the length of the pendulum and in the force of gravity.

95. How much the length of a pendulum is altered by any degree of heat, can only be known by experiments.

96. By an instrument for this purpose the length of a bar of metal may be very exactly measured, and found to be presently altered by the warmth of the hand.

97. When the force of gravity varies, the lengths of pendulums, that oscillate in the same time, are directly as that force.

98. By the length of a pendulum is always to be understood the distance between the point of suspension and the center of oscillation.

99. When the pendulum is a cylinder, the distance between these points is $\frac{2}{3}$ of its length.

100. Bodies of all kinds, when made into pendulums of the same length, perform their oscillations in times exactly equal.

101. A body, thrown in any direction not perpendicular to the horizon, describes a parabola.

102. The horizontal range of a project is as the sine, and the height to which it rises, as the versed sine, of double the angle of elevation.

103. The greatest horizontal distance equals twice the space, through which the body must have fallen to gain the velocity, with which it was projected.

104. Supposing the motion of the earth, a body thrown in a direction perpendicular to the horizon describes a parabola;

105. But must appear to us to move in a right line.

106. If a body moves in a curve, it is continually acted upon by some force, and this is called a centripetal force.

107. The endeavour of the body to recede in the opposite direction, in consequence of the first law of motion, is called a centrifugal force.

108. If the centripetal force tends constantly to the same point, the areas described round that point will be proportional to the times.

109. When bodies describe different circles with an equable velocity, the accelerating forces tend to the centers of those circles, and are as the semidiameters of the circles directly, and the squares of the periodic times inversely.

110. From this general rule, whenever it is known

known what is the ratio of the periodic times at different distances, it may be also known what is the ratio of the forces, and vice versa.

111. If the vis motrix, and not the vis acceleratrix is to be estimated, to the former ratios that of the quantities of matter must be added.

112. The centrifugal force, arising from the earth's revolution about its axis, must cause the ocean to assume a spheroidal figure.

113. The degrees of latitude are shorter near the æquator, than near the poles.

114. Though the centrifugal force of bodies increases as their quantity of matter, yet, supposing the earth in a fluid state, the densest bodies would accede to the center.

115. But should a fluid globe be turned so fast about its axis, that the centrifugal force should exceed that of gravity, the heavier bodies would rise in it, and the lighter sink.

116. When unelastic bodies meet, and the impact is direct, the velocity of them both after the stroke is the same, and in the same direction.

117. Let the two bodies be A and B, and let the motion be estimated in the direction of the body A, then as $A+B$ is to A, so is the difference between their velocities before the stroke, to the velocity gained by B.

118. If one or both the bodies be elastic, the
motion,

motion taken from one, and communicated to the other, is double what it is in hard bodies.

119. Therefore as $A+B$ is to $2A$, so is the difference of their velocities before the stroke, to the velocity gained by B .

120. If there is a row of equal elastic bodies contiguous to each other, and at rest, and an impulse is made upon the first, that and all the following will continue at rest, except the last, which will move away with the velocity which the first would have had, had it been alone.

121. If there is a row of such bodies continually decreasing in magnitude, they will all move in the direction of the impulse, and every one with a velocity greater, than that of the preceding.

122. If there is a row of such bodies continually increasing in magnitude, they will all move in a direction opposite to that of the impulse, except the last, whose motion will be equal to that, which the impulse would have produced in it, added to the sum of the motions of the preceding bodies.

123. The dispute between the Cartesians and modern Philosophers, whether the quantity of motion in the world is ever changed, may be thus determined: if we consider motion in all directions, it perpetually varies; but if we estimate the motion in one direction only, and call the opposite

finite motion negative, we know of no powers in nature, which can change its quantity.

124. Various experiments have been made with bodies falling into soft clay, or upon the arms of a balance, or moved by springs, to shew that the force of bodies in motion is proportional to the square of their velocities.

125. Most of these experiments succeed as they are described;

126. But they do not prove the point they are brought to prove:

127. Nor can the question be ever determined by experiments.

ASTRO-

ASTRONOMY.

1. **T**HE principles of Astronomy cannot be proved by experiments, properly so called.
2. But some of the appearances in the heavens, and the reasons of them, may be illustrated by machines contrived for that purpose.
3. The different systems of the world explained.
4. The order, distances, magnitudes, and periodic times of the primary planets, according to the Copernican system.
5. Conjectures concerning the distances and magnitudes of the fixed stars.
6. The divisions of the ecliptic and other circles.
7. The apparent diurnal rotation of the heavens must be the same, whether they really move round the earth, or the earth turns in the same time about its own axis.
8. The apparent annual motion of the sun must be the same, whether the sun goes about the earth, or the earth about the sun.
9. Reasons to believe, that both these motions are in the earth.
10. To find the place of the earth in its orbit, or the apparent place of the sun at any time of the year.

11. The

11. The earth's motion in it's orbit is not equable.

12. But it describes about the sun areas proportional to the times.

13. The earth is nearest to the sun in the midst of winter.

14. The earth's axis is inclined to the plane of its orbit.

15. To find the length of the day or night in any part of the earth at any time of the year.

16. The various paths, which the sun seems to describe above the horizon to those, who live in a right, oblique, or parallel sphere.

17. The risings and settings of the fixt stars which are called cosmical, acronychal, and heliacal.

18. An easy method of drawing a sun-dial upon any given plane.

19. The style of every dial must be parallel to the axis of the earth.

20. The shadow upon a dial may go backwards in some places upon the earth's surface.

21. Time, as measured by the sun's motion, does not flow equably.

22. The methods of finding when an instrument, which measures time exactly, goes before or after the sun.

23. Several methods of finding the latitude of a place.

24. An

24. An explanation of a paradox, which asserts, that of two places A and B, if A is east of B, it does not follow, that B is west of A.

25. A method of finding the longitude of any place upon land.

26. The difficulty of discovering it at sea, with an account of the principal methods, in which it has been attempted.

27. The præcession of the æquinoxes explained.

28. The sun turns about its axis.

29. The inferior planets can never appear ninety degrees distant from the sun,

30. They have two different conjunctions with him.

31. When Venus is seen in the morning, and when in the evening.

32. The superior planets may have any angular distance from the sun.

33. In what situation the planets are stationary, when they move forward, or according to the order of the signs, and when backward or contrary to that order.

34. Their latitudes, as seen at the sun, and at the earth.

35. The method of discovering the proportion of the earth's distance from the sun, to the distances of the planets.

36. The method of finding their periodic times.

B

37. The

37. The squares of their periodic times are, as the cubes of their distances from the sun.

38. It is probable, that every planet turns about an axis.

39. Comets are a kind of primary planets moving in very excentric orbits.

40. More are seen in the hemisphere next the sun, than in the opposite.

41. The course of some of them is from west to east, of others from east to west, and their orbits are differently inclined to the ecliptic.

42. Hence it appears, that the planets are not moved in their orbits by vortices.

43. Of the secondary planets one goes round the Earth, four round Jupiter, and five round Saturn.

44. The different phases of the moon explained.

45. The moon's distance from the earth and magnitude.

46. The difference between a synodical and periodical month.

47. The periodical month is exactly equal to the time, in which the moon turns about its axis.

48. Therefore the same side of the moon is constantly towards the earth.

49. The inclination of the moon's orbit, and the motion of its nodes.

50. The

50. The tides are raised by the moon twice in about 25 hours;

51. And are at their greatest height about three hours after the moon has passed the zenith, or nadir of the place.

52. The difference between spring and neap tides.

53. In summer the tides raised by the moon, when above the horizon, generally exceed those raised by her, when below it; the contrary happens in winter.

54. The satellites of Jupiter and Saturn appear to move from west to east, and from east to west by turns.

55. The appearances of Saturn's ring explained.

56. All the satellites eclipse, and are eclipsed by the primary planets, to which they belong.

57. To determine the shape of the shadow and penumbra, when a luminous globe shines upon an opake one.

58. To determine when there will be an eclipse of the moon, and whether it will be total or partial.

59. To determine the same things concerning an eclipse of the sun.

60. To apply these rules, the exact situation of the sun, moon, and earth, in one of the next remarkable eclipses will be represented.

HYDROSTATICS

AND

PNEUMATICS.

1. **T**HE density and specific gravity of a body is proportional to the quantity of matter contained in it, when the bulk is given.

2. The parts of fluids are heavy, and by their weight press both upon other bodies, and upon one another.

3. The weight of any quantity of a fluid is the same within a fluid of its own kind, as in vacuo.

4. All the particles of a fluid at rest press equally in all directions.

5. If the sides of a vessel are perpendicular to the bottom and to the horizon, the pressure of a fluid upon the bottom is equal to its weight.

6. In other cases it may be greater or less.

7. Therefore by altering the form of the vessel any quantities of a fluid, however unequal, may be made to press equally upon the bottom.

8. But yet these vessels will not press equally upon what is below them, or be equally heavy.

9. For where the vessel is narrower at the top, part of the weight is taken off by the pressure upwards.

10. The pressure upwards of a small quantity of water may be so great, as to raise a weight of several hundred pounds.

11. The pressure upon any part of the bottom or side is, as the area of that part, the perpendicular height of the fluid above it, and its specific gravity.

12. When the pressure of a fluid, upon one side of the vessel containing it, is in part removed, the effect of the opposite pressure is immediately perceived.

13. The perpendicular heights of fluids, contained in vessels communicating with each other, are reciprocally, as their specific gravities.

14. A solid, immersed in a fluid of the same specific gravity, will continue at rest, wherever it is placed.

15. If the weight of the solid be greater or less, than the weight of a quantity of fluid equal to it in bulk, it will descend or ascend with a force equal to the difference of those weights.

16. The ascent of a body in a fluid specifically heavier is owing to the pressure of the fluid upwards.

17. When this pressure is taken off, the body will not ascend.

18. This pressure may be so great as to sustain a body, whose specific gravity has any assignable

22 HYDROSTATICS, &c.

ratio to that of the 'fluid, provided the pressure downwards be taken off.

19. The part of its weight, which a body loses by being immersed, is to the whole, as the specific gravity of the fluid, to that of the solid.

20. This part is communicated to the fluid.

21. The opinion of Mr. Leibnitz, that a fluid with a solid immersed weighs less, while the solid is falling, than when it is sustained, is either true or false, according to the different manners, in which the solid may fall or be sustained.

22. When a body floats, the part immersed is to the whole, as the specific gravity of the solid, to that of the fluid.

23. Several kinds of hydrometers are made upon this principle.

24. The greatest burthen of a ship may be found from knowing its bulk.

25. A method of raising great weights from the bottom of the sea.

26. By weighing a solid both in vacuo, and in a fluid, the proportion of the specific gravities of of that solid and fluid may be known.

27. By weighing several solids in the same fluid, the proportion of their specific gravities may be known.

28. As also that of several fluids, by weighing the same solid in them.

29. The velocity, with which a fluid will spout

spout from an hole in a vessel, may be found experimentally, either by observing the parabola it describes, or the quantity flowing out in a given time.

30. By the former method the velocity appears to be that, which an heavy body acquires by falling the whole height of the fluid above the hole.

31. By the latter that, which is acquired by falling only half the height.

32. The reason of this difference.

33. When a fluid issues from the side of a vessel in a line parallel to the horizon, it will fall upon an horizontal plane, passing through the bottom of the vessel, at the greatest distance, if the hole is in the middle of the vessel's height.

34. And it will fall upon the same part of that plane from two holes, equally distant from the top and bottom of the vessel.

35. When a fluid spouts directly upwards, it rises nearly to the height of the surface of the stagnant fluid.

36. The causes, which prevent its rising exactly to that height.

37. The height and the distance, to which a fluid spouts, in all the different elevations of the jet, may be determined by the rules concerning projectiles.

38. The velocity of a fluid issuing at holes of

dif-

24 HYDROSTATICS, &c.

different depths, and the quantity coming out in a given time are in a subduplicate ratio of the depths.

39. The velocity of a fluid, issuing at a hole in the bottom or side of a cylinder, is uniformly retarded.

40. The manner of measuring time by water, running out of a vessel.

41. The resistance, which a body suffers by moving through a fluid, is equal to the force, with which a stream of that fluid acts upon the body, when it falls against it with the same velocity.

42. This force is as the square of the velocity.

43. And if the body be a globe, as the square of its diameter.

44. When bodies of the same weight begin to move through a fluid with the same velocity, that, which has the greatest magnitude, will soonest lose its motion.

45. When bodies of the same magnitude begin to move through a fluid with the same velocity, that which has the least weight, will soonest lose its motion.

46. Another kind of resistance in fluids arises from their tenacity.

47. The air is an elastic fluid, or one, whose dimensions are increased by diminishing the pressure upon it, and diminished by increasing the pressure.

48. Its density is always as the compressing force.

49. Air may be made to expand itself, till it takes up 1000 or 10000 times the space it ordinarily possesses; and how much farther it is capable of being rarified, is not yet discovered.

50. There is air contained in the pores of most bodies, which, when the external pressure is removed, expands itself and produces various appearances.

51. Air may be reduced to a third or fourth part of its usual dimensions; and how much farther it might be condensed cannot be known, because its force soon becomes so great, as to burst the strongest vessels.

52. Condensed air has various effects upon bodies placed within it.

53. The air is heavy, and its weight produces just the same effects, as its elastic force.

54. Its weight is able to sustain a column of mercury, whose perpendicular height is about 30 inches.

55. When the quantity of air, pressing upon the stagnant mercury, is lessened, that in the barometer sinks; when increased, it rises.

56. Several methods have been taken to make small changes in the height of the mercury the more easily perceived, as inclining the tube, adding a wheel to it &c.

26 HYDROSTATICS, &c.

57. The height of a column of any other fluid, which is sustained by the pressure of the air, is to that of mercury, as the specific gravity of mercury, to that of the fluid.

58. The ascent of water in various kinds of syphons and pumps is owing to this pressure of the atmosphere.

59. But in all engines, which raise water, as much force is exerted in working them, as would be sufficient to lift the same quantity of water to the same height.

60. In common syphons the fluid is always conveyed from an higher place to a lower.

61. A syphon may be so contrived, that part of the fluid shall be conveyed to an higher place.

62. But to effect this, there must be at least as much motion of another part of the fluid downwards.

63. And this rule is general with regard to all machines, which are moved by a fall of water, and employed to raise it.

64. In engines made to extinguish fires, a continual stream of water is forced out by the spring of the included air.

65. Fountains of several sorts are made by the weight and elastic force of the air.

66. It is easy to find the weight of a column of the atmosphere, whose base is given.

67. That which presses upon a man's body exceeds 30000 pounds.

68. A force, which appears to be very great, when it acts only in one direction, will not affect the most tender substances, if it acts equally on all sides.

69. The nature of the diving-bell explained.

70. Fresh air may be conveyed to it, whenever a vessel can be let down to a greater depth than the bell.

71. The rarified air may be let out.

72. The manner of measuring the depth of the sea, where it exceeds the length of any lines, which can be procured.

73. When the air in any place is rarified by the removal of any part of it, the denser air will press into that place.

74. But this will not happen, when the air is rarified by heat only.

75. The manner, in which winds are produced.

76. Especially those, which blow between the tropics.

77. The manner, in which vapours are raised, and dew or rain formed.

78. Smoke and other light bodies, which ascend in the air, fall again in an exhausted receiver.

79. Respiration and suction are performed by the help of the air's pressure.

80. The

28 HYDROSTATICS, &c.

80. The death of animals in an exhausted receiver, is not owing to the pressure of the air included in their bodies upon their lungs.

81. Air, filled with such sulphureous vapours as are prejudicial to animals, will also extinguish flame.

82. Air is necessary for preserving fire.

83. Even gunpowder will not catch fire in vacuo.

84. On the contrary, several kinds of phosphorus shine most in an exhausted receiver.

85. Quicksilver shaken in a vessel, from which part of the air is drawn, becomes luminous.

86. The moisture or dryness of the air is discoverable by several kinds of instruments.

87. The heat or cold of it by others.

88. A small degree of heat will make water boil, when the pressure of the atmosphere is removed.

89. All violent agitations of the small particles of bodies produce heat.

90. Sound arises from a tremulous motion of the particles of the sounding body.

91. This motion is propagated by the air.

92. The sound of a bell included in a receiver becomes gradually weaker, as the air is drawn out, till it is intirely lost.

93. By placing the bell in condensed air, the sound is made more intense.

94. When

94. When very small glass tubes are dipt into water, the attraction of the glass will raise the water, and suspend it at an height, which is inverfly, as the diameter of the tube.

95. And if two such tubes, communicating with each other, are in part filled with water, its surface will be higher in the less tube.

96. The particles of mercury attract each other with more force, than they are attracted by glass.

97. And therefore in small glass tubes, communicating with each other, the surface of the mercury will be lower in the less tube.

98. If a tube be dipt into water so far, that its height above the surface is less, than the height, to which the attraction can raise it, yet the water will not flow over the top.

99. When a tube is filled with water and not dipt, the length of the column suspended is somewhat greater, than when one end of it is under water.

100. The attraction, with which the parts of water act upon each other, occasions this difference.

101. The perpendicular height of the water is the same, if the tube is inclined.

102. The upper surface is in this case circular.

103. Let the tube be taken out of the water and laid parallel to the horizon, then the fluid will recede from the end which was dipt, if the tube

30 HYDROSTATICS, &c.

is cylindrical, only a little way; but if conical, to its vertex.

104. This motion of the water in a conical tube is not owing to any advantage, with which the smaller end of the tube acts upon it, but to the direction, in which every part of the glass attracts it.

105. If a capillary syphon be filled with water and not immersed, the water will not flow out of the longer leg, unless the difference of the legs exceeds the height, to which the shorter can raise it.

106. But if the shorter leg is immersed, it will run as through a larger syphon.

107. When the tube is composed of two parts, whose diameters are different, the height of the water suspended is the same, as if the tube had every where that diameter, which it has at the upper surface.

108. This experiment will not succeed, unless the parts of the tube are joined in such a manner, as to exclude the pressure of the air.

109. The weight sustained by the glass is exactly the same, as in the simple tube, the pressure of the air supporting the rest of the water, when the tube is larger at the bottom; and adding to the weight, when it is less.

110. No objection to this account can be drawn from the success of the common experiments in an exhausted receiver.

OPTICS.

OPTICS.

1. **L**IGHT consists of small and distinct particles, which are subject to the same laws as other bodies.

2. It is continually emitted from luminous substances in right lines.

3. But may be turned out of its straight course by the action of other bodies upon it.

4. Its motion is most affected by those bodies, upon which it acts most strongly.

5. The methods of finding the velocity of light explained.

6. The shape of shadows may be determined by considering, that light always moves in right lines.

7. And by their lengths the heights of buildings &c. may be found.

8. The rays of light are bent, when they pass by the edges of bodies, and those rays are most bent, which pass at the least distance.

9. When light is turned back by reflection, the angle of reflection lies in the same plane with, and is equal to the angle of incidence.

10. Hence we have another method of taking heights.

11. When light enters a denser medium, it is

re-

refracted towards the perpendicular; when a rarer, from it.

12. The angle of refraction lies in the same plane with, and its sine is in a given ratio to that of the angle of incidence.

13. When light passes out of air into water, the sines of incidence and refraction are to each other, nearly as 4 and 3; when into glass, as 3 and 2.

14. The refraction of the atmosphere raises the apparent places of all the heavenly bodies, which are not in the vertex.

15. And makes the sun and moon, when near the horizon, appear oval.

16. Parallel rays, reflected or refracted by one or more plane surfaces, continue parallel.

17. When converging or diverging rays fall upon any plane surface, they continue to converge or diverge.

18. And the distance of the focus from the surface is, to the distance of the focus of incident rays, as the sine of incidence, to that of reflection or refraction.

19. Parallel rays falling upon a spherical surface are made to converge or diverge.

20. When they are reflected, or refracted into a denser medium, the focus lies on the concave side of the surface; when they are refracted into a rarer, on the convex.

21. In all these cases the distance of the focus from the surface is to its distance from the center, as the sine of incidence, to that of reflection or refraction.

22. Whenever the place of the principal focus is known, the focus of diverging or converging rays may be thus found: the distances of the principal focus from the focus of incident rays, from the center, and from the focus of refracted or reflected rays are in continual proportion.

23. Hence the focus of all lenses may be found.

24. Refracting surfaces having two principal focuses, in the two first terms of this proportion the focus of rays coming the contrary way is to be taken; in the two last, the other.

25. By the center is meant the point, through which, if a ray passes, it is either not turned out of its straight course, or returns into it again.

26. When the rays are reflected, if the focus of incident rays moves, that of the reflected rays moves in the contrary direction, and they meet at the center and at the surface.

27. When they are refracted, the two focuses move in the same direction.

28. These rules relate principally to a pencil, whose axis coincides with that of the glass, but they are very nearly true of others, when the inclination is not great.

29. Where the rays of each pencil are united, a distinct image will be formed.

30. An image may serve instead of an object, and thus a second image will be formed, which will occasion a third, that a fourth, &c.

31. When an object is placed between two plane specula parallel to each other, there is formed by each speculum a row of images, which as they are more remote are gradually fainter, till they become invifible.

32. When the two specula are inclined to each other, as many images are formed by them, as there are angles, equal to that contained between them, in its compliment to four right angles.

33. The linear magnitude of the image is to that of the object, as its distance from the center, to that of the object.

34. It is erect, when it is on the same side of the center, with its object; inverted, when on the other.

35. From hence may be seen the reason of all the appearances, in the magic-lantern, and in all the various kinds of the camera obscura.

36. The use, of what is called the solar microscope, depends upon the same principles.

37. The pictures of small objects may be magnified by this instrument many thousand times, and yet continue distinct.

38. The

38. The sun's image is formed in the focus of a glass, exposed to the sun's rays.

39. In the focus of some glasses the heat is more violent, than any other that is known.

40. By observing the breadths of the glasses, and the distances of their focuses, the density of the rays in their several burning spots may be compared with each other, or with the density of the sun's direct rays.

41. When rays of light enter our eyes, they are refracted by the humours, and form images of the objects they come from.

42. If they are well formed, or the rays of each pencil exactly united at the bottom of the eye, vision is distinct.

43. This could only happen when the objects were at one certain distance, if the shape of the eye and the situation of it's humours were constantly the same.

44. The changes, which might be made in the eye so as to render the picture distinct, while the distance of the object varies, may be seen in an artificial eye.

45. The defects of such eyes, as unite the rays either before the retina or beyond it, may be remedied by glasses.

46. Short-sighted persons can see distant objects best, when they are strongly illuminated;

47. But can see near objects with less light, than they who have perfect eyes.

48. The reason, why the inferior planets appear to the naked eye constantly round, though by a telescope they are found to have the same variety in their phases, as the moon.

49. The breadth of the picture at the bottom of the eye is reciprocally, as the distance of the object.

50. The picture is nearly of the same brightness at all distances of the object.

51. We are able to see by quantities of light exceedingly different.

52. Common day-light exceeds the light of the full moon at least 90000 times.

53. In looking with one eye at any broad object, placed directly before us, a part of it is not visible.

54. Habit prevents this from being commonly observed.

55. It is from habit, that we imagine an object, seen with both eyes, to be single or double.

56. It is habit also, which enables us to judge of distances by sight.

57. Our judgments of the distance and the magnitude of an object are generally connected.

58. Neither the divergency of the rays coming from the same point of an object, nor its distinctness, nor brightness, nor the angle between the
optic

optic axes, nor the interval between the pupils usually suggests to us the distance.

59. The apparent magnitude of an object seen either by the naked eye or with glasses, is measured by the angle, which the rays coming from the extremities of it, make when they fall upon the eye.

60. Hence the general principles of perspective may be explained.

61. And a method may be found of drawing deformed pictures, which appear to have just proportions, to an eye in one situation.

62. When an object is seen through a convex lens or in a concave speculum, the apparent magnitude is always either equal to or greater than its magnitude to the naked eye.

63. When it is seen through a concave lens or in a convex speculum, the apparent magnitude is either equal to or less than the true.

64. If an object be so placed before a cylindrical reflecting surface, that one diameter is parallel to the axis of the cylinder, that diameter will appear of its just length; all the others will be increased, if the surface is concave; diminished, if it is convex.

65. Hence may be found the method of drawing deformed pictures, which will appear regular in a cylinder, placed on the plane of the draught.

66. A piece of perspective may be so placed before a concave speculum, that it shall appear larger

larger and more projected, than when it is seen by direct rays.

67. It is seen with the same advantages through a convex lens.

68. The part of a fixt object, seen in a given part of a glass, is greatest, when the eye is close to the glass; least, when it is close to the image.

69. In a plane speculum a man sees an equal part of his own body at all distances, and the length and breadth of this part are half those of the glass.

70. Several kinds of telescopes may be formed by combinations of specula and lenses.

71. These glasses must be so placed, that the rays of the same pencil may be nearly parallel, when they fall upon the eye.

72. In all kinds of telescopes, which have only one eye-glass, the apparent magnitude is to the true, as the focal length of the object-glass, to that of the eye-glass.

73. When more glasses are added, whose focal lengths are equal, the apparent magnitude continues the same.

74. The magnifying power of a telescope may be increased either by increasing the focal length of the object-glass, or by diminishing that of the eye-glass.

75. But if the proportion of their focal lengths is too great, the object becomes indistinct.

76. A

76. A concave reflecter will bear a much shorter focus without confusion, than a lens of the same focal length.

77. When we use one convex eye glass the object is inverted ; but it is erect, when we use one concave, or three convex eye glasses.

78. The visible area is much smaller, when the eye glass is concave, than when it is convex.

79. The proper distance of the eye from the first glass, if it is convex, equals its focal length ; but if it is concave, the eye should be as near it as possible.

80. Any transparent globe or lens, whose focal length is very small, will serve for a microscope.

81. The apparent magnitude of an object, seen in such a microscope, is to its true magnitude, when seen distinctly by the naked eye, as the least distance, at which it can be thus seen, to the focal length of the glass.

82. In a microscope formed of two lenses, the linear magnitude of the image exceeds that of the object, in proportion as its distance from the first glass exceeds the distance of the object : and this picture is again magnified, as in a single microscope.

83. In a single microscope, the apparent situation of the object is not altered ; in a double one, it is inverted.

84. The light of the sun or of any luminous body consists of rays, which differ in colour.

85. These colours are not changed by reflection or refraction.

86. Bodies of any strong colour reflect the rays of that colour most copiously.

87. By a mixture of rays of two or more colours, one may be produced different from all those which compose it.

88. These rays may be again separated, and each sort will retain its original colour.

89. The whiteness of the sun's light is compounded of all the primary colours.

90. Whiteness may arise from rays of different colours, which enter the eye separately, if the intervals between them are sufficiently small.

91. The rays, which differ in colour, differ also in degree of refrangibility.

92. The rays, which are more refrangible, than others, are also more reflexible.

93. Reflection of light is not caused by its impinging upon the solid parts of bodies.

94. The transparency of bodies seems to arise from their having small pores, equably distributed.

95. The rays of light are by turns more easily refracted and reflected.

96. The refraction of Iceland Crystal explained.

97. The primary rainbow is caused by two refractions and one reflection of the sun's light in drops of water.

98. The rays, by which it is seen are those, which make the greatest angle with the incident rays, when they come from the drop.

99. The colours lie in the same order, as in the sun's image formed by a prism; that of the most refrangible rays being on the inner side.

100. The secondary rainbow is caused by rays twice reflected and twice refracted.

101. The rays by which it is seen are those, which, when they come out of the drop, make the least angle with the incident rays.

102. The order of the colours is contrary to that in the primary rainbow.

103. The secondary rainbow is fainter than the primary, and less frequently seen.

F I N I S.

07. The primary rainbow is the first of two
reflections and one reflection of the light in
drops of water.

08. The rays by which it is seen are those
which make the greatest angle with the incident
rays when they come from the drop.

09. The colour is in the same order as in the
sun's rays formed by a prism; that is, the most
refrangible rays being on the inner side.

10. The secondary rainbow is caused by two
reflections of the light in the drops.

11. The rays by which it is seen are those
which when they come out of the drop make
the least angle with the incident rays.

12. The colour is contrary to
that in the primary rainbow; that is, the most
refrangible rays being on the outer side.

4 OC 58

